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EXPERIMENTAL INVESTIGATION ON PERFORMANCE CHARACTERISTICS OF A DIESEL ENGINE WITH PISTON USING ALUMINIUM LM25 ALLOY REINFORCED WITH B_4C AND GRAPHITE PARTICULATE

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ABSTRACT

At present, aluminium has an enormous demand in the field of engineering and aerospace sectors. But this systematic advancement desires somewhat new apart from aluminium. In this investigation, aluminium LM25 alloy is taken as a base matrix material, while boron carbide and graphite particulate is exploited as a reinforcement. Stir casting technique, which is a fluid state procedure, is utilized for the manufacture of the metal matrix composites. Four distinctive MMC specimens were produced with 5% B4C and 5% graphite, 6.5% B4C and 3.5% graphite, 7.5% B4C and 2.5% graphite are utilized as samples. Mechanical properties like tensile strength, hardness and wear test are studied on the composite specimens. Morphological studies are also examined on the tested samples using Scanning Electron Microscopy (SEM) to detect the bonding among reinforcements and matrix. The results were plotted and graphically demonstrated to convey those materials characteristics. From the tensile results, it is noticed that the strength increased with increase in the percentage of reinforcement, and hardness also increased with the percentage of reinforcement in the sample. In this investigation, prepared a piston with reinforced composition of 6.5% B4C and 3.5% graphite. This prepared piston is made to run on a diesel engine and evaluated the performance characteristics of a diesel engine. Experimental results showed that the performance characteristics of a diesel engine are improved by using aluminium LM25 alloy piston.

KEYWORDS: MMC, Mechanical Properties, Aluminium, B_4C, Graphite, SEM & Diesel Engine

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Original Article

INTRODUCTION

Metal matrix composite offers superior substantial and synthetic properties when contrasted with predictable alloys, which is anticipated for different demands. Aluminum alloy will supplant the metallic element in designing purposes. Ordinary aluminum is flexible and eminent because of their horrendous wear resistance. This issue will be overwhelmed by considering hard ceramic particles as a reinforcement to enhance its properties like hardness and strength. Boron carbide (B_4C) empowers aluminium LM25 alloy, the protection from the substance assault and quality maintenance at elevated temperatures.

The literature survey related to aluminium LM25 alloy and its composites are as follows. Baradeswaran et al. [1] researched that the hardness and strength of the aluminium composite reinforced with boron carbide gradually increased with increment in level of boron carbide. Thirumalai Kumaran et al. [2] researched on dry sliding wear conduct of AA6351 alloy on the wear test variables with 5 wt% silicon carbide-reinforced composites

and 5 wt% boron carbide. From the experimental results, enhancement of wear resistance was accomplished with the consideration of a limited quantity of the materials. Md. Habibur Rahman et al. [3] investigated that the resistance to wear at engaging surface is significantly improved and silicon carbide present in the metal matrix composite (aluminium) is improved. Boopathi et al. [4] investigated on the fly slag reinforcements and silicon carbide into the aluminium alloy (Al-2024). The experimental results demonstrated that the expansion in rigidity and the enlargement of unreinforced aluminium is higher than that of hybrid metal matrix composite. B. Veeresh Kumar et al. [5] noticed that there is a development in tribological and mechanical properties. From their experimental results, it is demonstrated that with the reinforcement of silicon carbide, the composites densities are enhanced. Sujan et al. [6] examined the abilities of SiC and Al_2O_3 reinforced metal matrix composite materials with the employment of stir casting method. Experimental work revealed that the recently manufactured material expense on rough wear to be at a lower rate. Abdullah et al. [7] demonstrated that the mechanical properties like hardness and strength is enhanced by using aluminium composite with the reinforcement of particle. Mohanavel et al. [8] worked on stir casting technique using metal matrix composite AA7075 reinforced with an alternate weight portion of fly dust. It is observed that the mechanical properties are enhanced by using aluminium composites. Sridhar et al. [9] researched on the attributes of A356 composite reinforced with ash remains are done with the employment of stir casting technique. From the experimental results, it was proposed that the utilization of bottom ash is the best substitute for the composite A356 alloy. Liang Y. N. et al. [10] revealed that the silicon carbide particles comprising metal matrix composites demonstrated that there is an increment in wear resistance. Din Bandhu et al. [11] considered Al 7075 as a base material, ceramic materials like SiC, Al_2O_3, B_4C and TiB_2 are utilized as reinforcements. Mechanical properties like hardness and tensile strength were examined for the arranged samples. Atrian et al. [12] considered that the categorization and amalgamation of aluminium alloy Al7075 fortified with silicon carbide in association with mechanical conduct. The expansion in hardness and strength is found out by the incorporation of nanoparticles into the composite. Chauhan et al. [13] researched on the composites of alumina by changing the percentage of reinforcement and noticed that the elasticity property is enhanced with the accumulation of Al_2O_3 and fly ash. Praveen Kittali et al. [14] assessed the impacts of Al_2O_3, B_4C and SiC fortifications on the mechanical conduct of AMMCs delivered by various strategies, for example, stir casting, powder metallurgy and so on. Veeresh Kumar et al. [15] utilized Al6061–SiC and Al7075–Al_2O_3 composites and both composite results are compared. The uniform dispersion of the particles in the MMC is uncovered by the investigation of micro-photographs of composites.

In present investigation, stir casting technique is used. In this method, preheated reinforced materials are added to a molten metal utilizing a stirrer and the liquid composite material is poured in required moulds. The reinforcement used in the present work is B_4C and graphite with matrix material as aluminium LM25 alloy. The fabricated samples are tested for the evaluation of mechanical properties. In this investigation, the properties of Group-2 is higher than other groups. Hence prepared a piston with reinforced composition of Group-2 (6.5% B_4C and 3.5% graphite). This prepared piston is made to run on a diesel engine and evaluated the performance characteristics of a diesel engine.

MATERIALS AND METHODS

Composite Fabrication

The synthesis of metal matrix composite used in the study was carried out by the stir casting process. An aluminium alloy of LM25 was purchased from Vision castings Pvt. Ltd. Hyderabad, Telangana. Liquid state metal is generally utilized for enhancing composite materials where preheated reinforcement materials are added to the molten metal at a speed of 500

rpm. After the accumulation of reinforcement, stirring has to be done for 4–6 minutes for accurate mixing. The melt was kept in the crucible for nearly half minute and then it was poured into the die and the fabricated samples are demonstrated in Figure 1. Keeping the 5% B_4C and 5% graphite, 6.5% B_4C and 3.5% graphite, 7.5% B_4C and 2.5% graphite, such four arrangements of specimens are set up for four different compositions. The acquired specimens from the mold are seen in Figure 2 and are machined to the desired requirement.

(a) **(b)**

Figure 1: Stages of Preparation of Metal Matrix Composites a) Melting and Stirring b) Pouring.

Figure 2: Fabricated Hybrid Composite Specimens.

Table 1: Composition of Reinforcement

Metals	Group-0	Group-1	Group-2	Group-3
B_4C	-	5%	6.5%	7.5%
Graphite	-	5%	3.5%	2.5%

Tensile Test

The tensile test was carried out in computerized Universal Testing Machine (UTM) in room temperature at G. Pulla Reddy Engineering College, Kurnool. The tensile test was conducted on sample of specimen and the results are calculated for reinforcement of B_4C and graphite. In present work, a tensile test exerts a force to a material and determined the specimen’s response to the stress. It is also used to determine how sturdy a material is. The test setup and testing sample holding method is shown in Figure 3.

(a) (b)

Figure 3: Test setup for Testing the Composite Samples.

Hardness Test

(a) (b)

Figure 4: Brinell Hardness Test Setup and its Measurement Direction.

To test the hardness, Brinell hardness test was used. The test setup and its testing measurement direction are shown in Figure 4. The hardness of a LM25 alloy with reinforcement of B_4C and graphite is measured by hydraulically pressing a hard ball under a standard load into the specimen. A graph has been plotted to know the variation of the strength for various weight fractions. This indicates a good bonding between the base alloy and reinforcement shows the hard particles are successfully dispersed in the metal matrix**.**

Wear Test

In present study, wear test is done to find out the quantity of material removal during a particular time period in well defined conditions. To attain more precise predictions of wear, it is essential to carry out the wear test under the conditions representing the exact wear process. The wear test was conducted on every sample of specimen and the results are calculated for reinforcement of B_4C and graphite. Graphs have been plotted for the composite samples. The experimental setup for wear test is shown in Figure 5.

Figure 5: Wear Testing Machine.

Piston Manufacturing Process

For all tests, the value of Group-2 (6.5% B_4C and 3.5% graphite) is higher when compared to all other groups. Hence by taking the composition of Group-2, manufactured a piston by sand casting method. In sand casting method, the pouring of liquid metal into a sand mold (molds are usually arranged by means of a hollow shape) and letting it to coagulate within the mold. Different patterns are utilized to create cavity in the molds. In present investigation, wood pattern is used for manufacturing the piston, because of low, moderate and high production quantities, respectively.

Figure 6: Manufacturing process of Piston by Sand Casting Method.

Figure 7: Aluminium (LM25) Alloy Piston.

After that, an experiment is conducted on a diesel engine using prepared aluminium LM25 alloy piston and evaluated the performance characteristics of a diesel engine.

Experimental Procedure

A single cylinder, kirloskar compression ignition engine with DC generator has been chosen for investigation. Firstly, Fill the tank with diesel and turn over the engine utilizing vent valve assuring that no load on the motor. Then permit the engine for 10 minutes until it attains a steady position at no load condition. Note down the voltmeter, ammeter readings, time taken for fuel consumption, and manometer readings at no load conditions. Later, the engine is loaded with the copper plate in liquid rheostat. In the wake of applying the load on the engine at a fixed point and the corresponding readings are tabulated. At last the engine is to be stopped by hauling the lever in the direction of the engine cranking side and finally evaluated the performance characteristics of a diesel engine. Diesel engine setup is shown in Figure 8. The specifications of diesel engine are demonstrated in Table 2.

Table 2: Diesel Engine Specifications

Make	Kirloskar Make, Compression Ignition with D. C. Generator
No. of cylinders	one
Bore	80 mm
Coefficient of discharge (C_d)	0.62
Capacity	4 KW
Diameter of Orifice (d)	20 mm
Stroke	110mm
Compression ratio	16:1
Maximum Current	13 amps
Efficiency of dynamometer	80%
Armature voltage	220V

Figure 8: Diesel Engine Setup.

RESULTS AND DISCUSSIONS

Tensile strength

The tensile strength of the four samples is tested and an average of the tensile strength is noted. The plots are shown in Figure 9. It was observed that the distribution of reinforcement into the matrix results in an increase of tensile strength. Maximum tensile strength is observed that Al-LM25+6.5%B_4C+3.5%Graphite. The increase in tensile strength is due to the isolation of particles at some definite zone into the matrix phase.

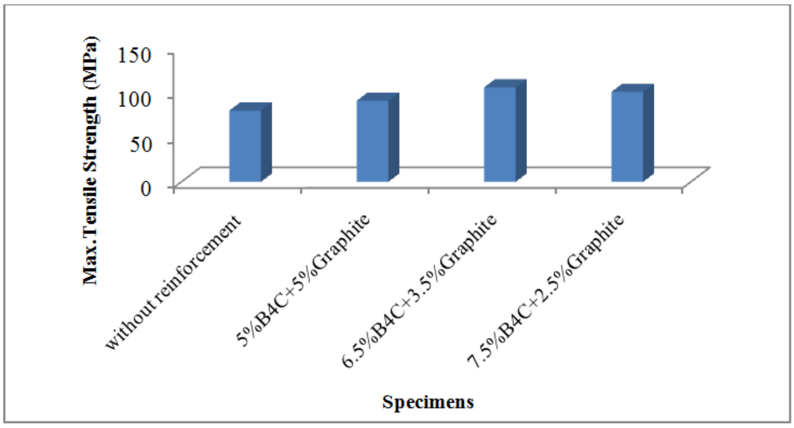


Figure 9: Tensile Strengths with varying Proportions of Reinforcements.

Brinell Hardness Number (BHN)

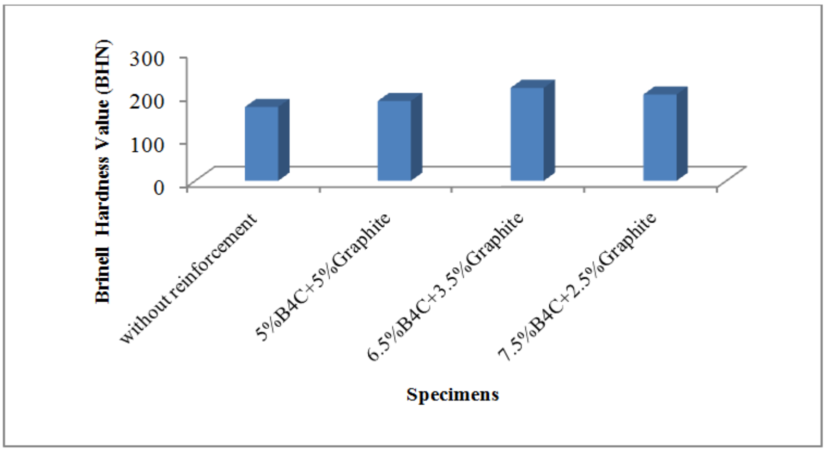


Figure 10: Brinell Hardness Number (BHN) with Varying Proportions of Reinforcements.

Brinell hardness is tested for 4 composite samples at different locations and an average value is shown in Figure 10. It is observed that the hardness is increased with increase in weight fraction of B_4C and graphite. Maximum hardness is observed at Group-2.

Wear Test

The wear test was conducted on every sample of specimen results are calculated for reinforcement of $B_4C$and graphite. Graphs are plotted between time versus wear, coefficient of friction and frictional force for all samples.

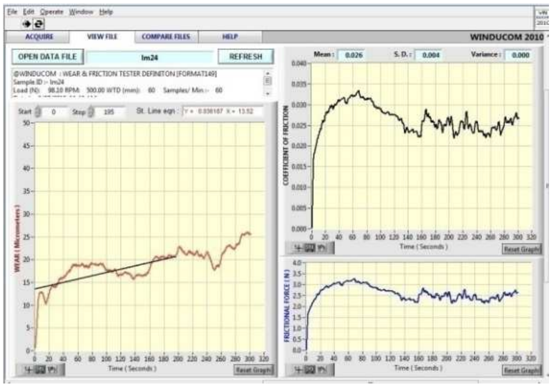


Figure 11: Wear test for Group-0.

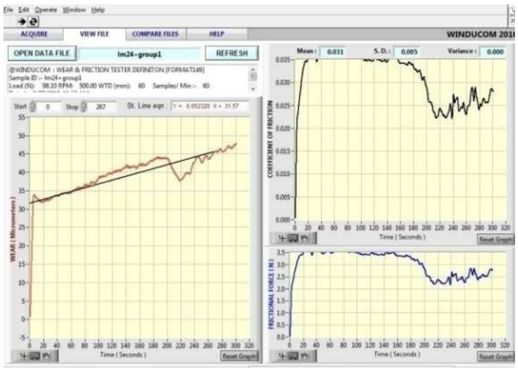


Figure 12: Wear test for Group-1.

Figure 13: Wear test for Group-2.

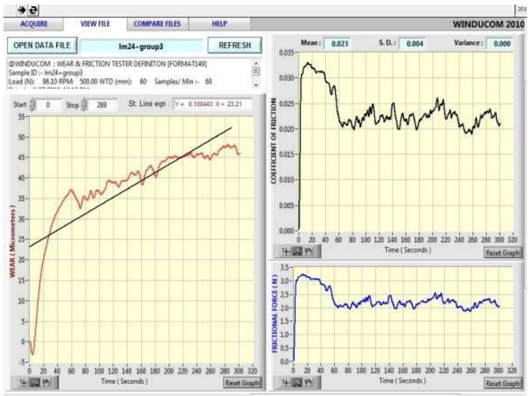
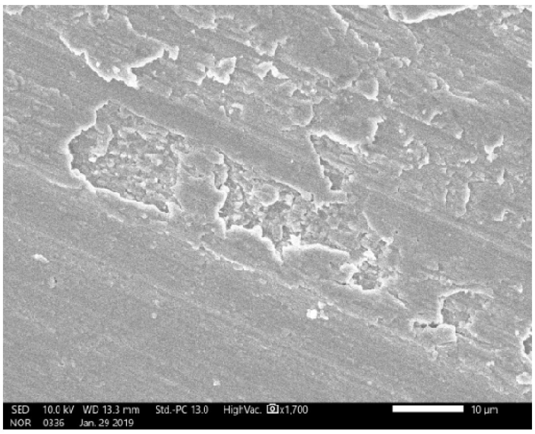


Figure 14: Wear test for Group-3.

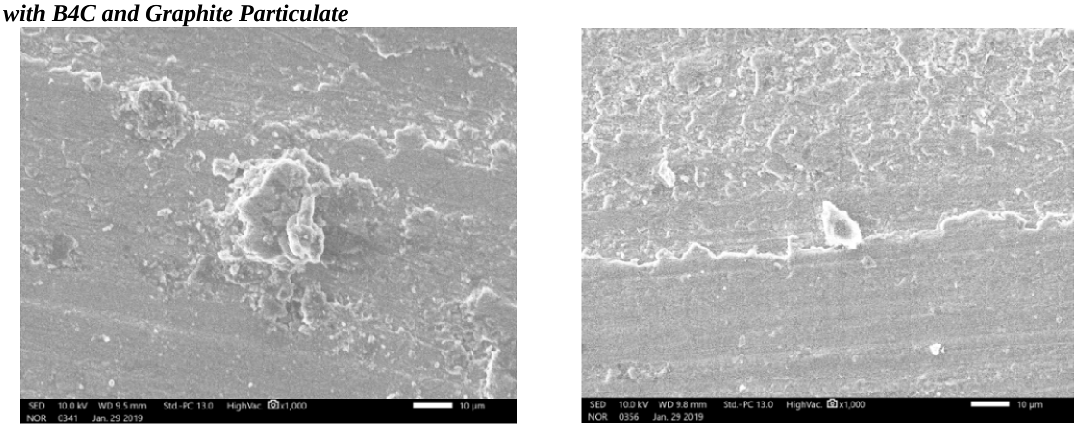
SEM Analysis

The tensile strength of the composite increases with the addition of B_4C and graphite is noted from the universal testing machine for different varying proportions. The reason for the increase in tensile strength is due to the presence of the interfacial gaps between the matrix and the reinforcement, which is unable to transfer the load from the matrix to reinforcing phase as can be seen from the optical micrograph. The microstructure represents that the Group-0, Group-1 and Group-3 contain voids at a specified location which tends to less tensile strength when compared with Group-2 sample microstructure, good bonding is obtained which results in good tensile strength. The microstructure of all composites is observed and represented in below figures.

(a)



(b)



(c) **(d)**

Figure 15: SEM Images of Specimens a) Group-0 b) Group-1 c) Group-2 d) Group-3.

Performance Characteristics

Brake Specific Fuel Consumption

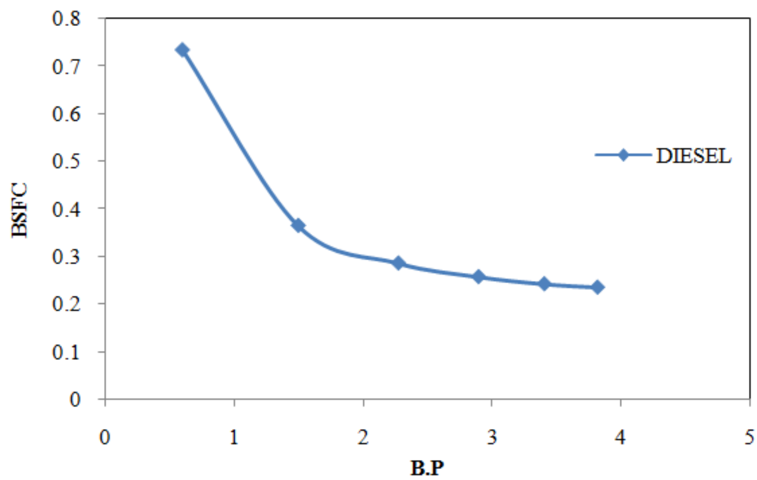


Figure 16: Brake Power Vs BSFC.

Brake Thermal Efficiency

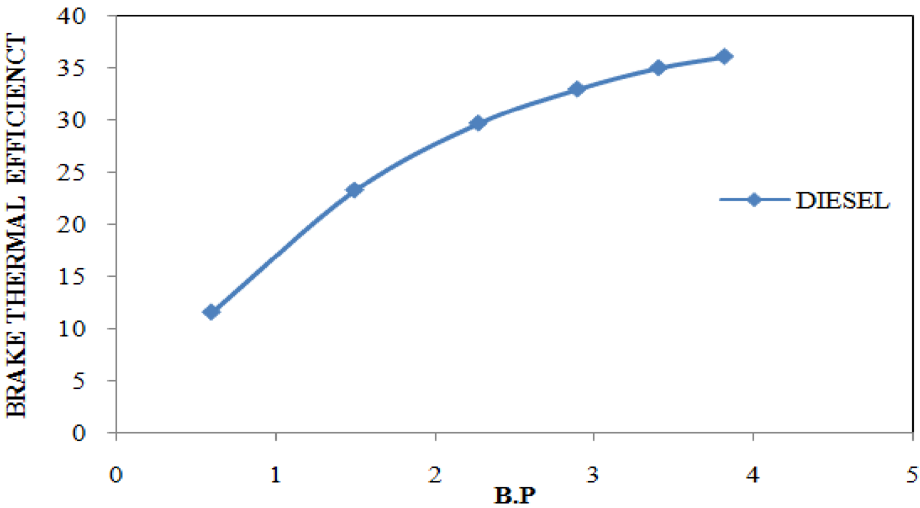


Figure 17: Brake Power Vs Brake Thermal Efficiency.

Indicated Thermal Efficiency

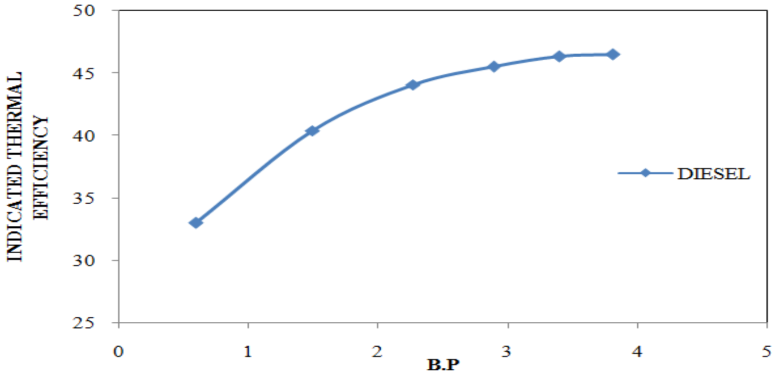


Figure 18: Brake Power Vs Indicated Thermal Efficiency.

Mechanical Efficiency

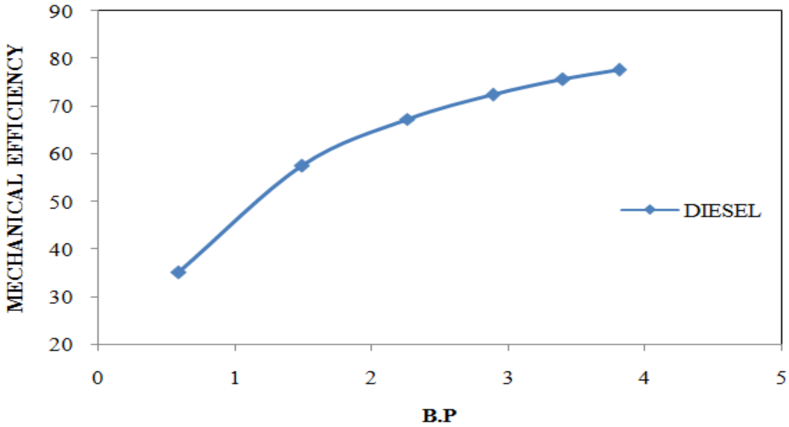


Figure 19: Brake Power Vs Mechanical Efficiency.

Volumetric Efficiency

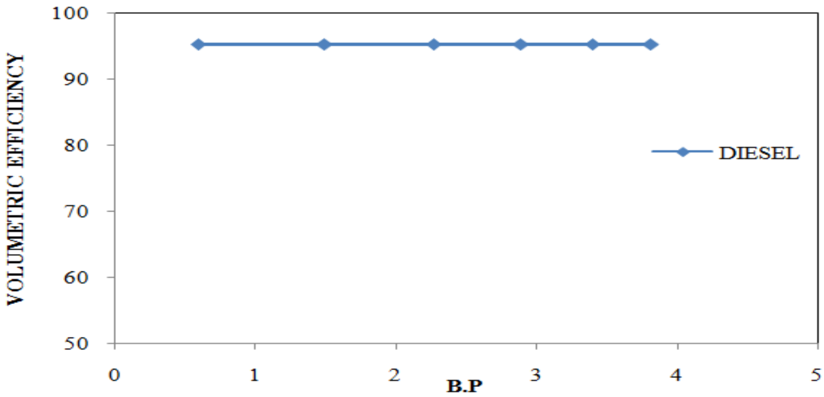


Figure 20: Brake Power Vs Volumetric Efficiency.

CONCLUSIONS

In present investigation, prepared a piston using aluminium LM25 alloy reinforced composition of Group-2 (6.5% B_4C and 3.5% graphite). This prepared piston is used to run on a compression ignition engine and evaluated the performance characteristics of a diesel engine. The following conclusions are drawn.

- The brake specific fuel consumption of the diesel is lower at all blends. It is observed that with increase in load, decreases fuel consumption of diesel. This is due to increment in percentage of the fuel which is necessary to run the engine is lower than the increment in the percentage of brake power as comparatively a smaller amount of heat losses at higher loads.
- The brake thermal efficiency and indicated thermal efficiency of the diesel is gradually increases with increase in load. This is mainly because of complete combustion of diesel fuel and rapid flaming is also one of the reasons for improving the efficiency.
- The mechanical efficiency of the diesel engine is increased with addition of load. This is mainly due to less friction. Higher compression ratio is also one of the reasons for improving mechanical efficiency.
- The volumetric efficiency of the diesel engine is significantly improved.

REFERENCES

1. *Baradeswaran, A. E. P. A., & Perumal, A. E. (2013). Influence of B4C on the tribological and mechanical properties of Al 7075–B4C composites. Composites Part B: Engineering, 54, 146-152.*
2. *Thirumalai Kumaran, S., & Uthayakumar, M. (2014). Investigation on the dry sliding friction and wear behavior of AA6351-SiC-B4C hybrid metal matrix composites. Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 228(3), 332-338.*
3. *Rahman, M. H., & Al Rashed, H. M. (2014). Characterization of silicon carbide reinforced aluminum matrix composites. Procedia Engineering, 90, 103-109.*
4. *Boopathi, M. M., Arulshri, K. P., & Iyandurai, N. (2013). Evaluation of mechanical properties of aluminium alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites. American journal of applied sciences, 10(3), 219.*
5. *Kumar, G. V., Rao, C. S. P., & Selvaraj, N. (2011). Mechanical and tribological behavior of particulate reinforced aluminum metal matrix composites–a review. Journal of minerals and materials characterization and engineering, 10(01), 59.*
6. *Sujan, D., Oo, Z., Rahman, M. E., Maleque, M. A., & Tan, C. K. (2012). Physio-mechanical properties of Aluminium metal matrix composites reinforced with Al2O3 and SiC. International journal of Engineering and Applied Sciences, 6.*
7. *Abdullah, Y., Daud, A. R., Shamsudin, R., & Harun, M. B. (2009). Flexural strength and fracture studies of al-si/sicp composites. International Journal of Mechanical and Materials Engineering, 4(2), 109-114.*
8. *Patel, B., & Subhedar, D. (2016). Experimental and Numerical Investigation of Diesel Engine Turbocharger. International Journal of Automobile Engineering Research and Development (IJAuERD) ISSN (P), 2277-4785.*
9. *Mohanavel, V., Kumar, S. S., Srinivasan, R. V., Ganeshan, P., & Anand, K. T. (2017). Mechanical and metallurgical characterization of AA7075-fly ash composites produced by liquid state method. Journal of Chemical and Pharmaceutical Sciences ISSN, 974, 2115.*
10. *HS, S., Prasad, T. B., Chandra, B. T., & KT, U. (2017). Evaluation of Mechanical Properties of A356 Alloy Reinforced with Bottom Ash Metal Matrix Particulate Composite. IJASRE, 3.*
11. *Liang, Y. N., Ma, Z. Y., Li, S. Z., Li, S., & Bi, J. (1995). Effect of particle size on wear behaviour of SiC particulate-reinforced aluminum alloy composites. Journal of Materials Science Letters, 14(2), 114-116.*

12. Bandhu, D., Thakur, A., Purohit, R., Verma, R. K., & Abhishek, K. (2018). Characterization & evaluation of Al7075 MMCs reinforced with ceramic particulates and influence of age hardening on their tensile behavior. Journal of Mechanical Science and Technology, 32(7), 3123-3128.

13. Jeyan, D. J. M., & Rupesh, A. (2015). Experimental Investigations on the Performance and Exhaust Emissions of a Diesel Engine Using Jatropha Oil as a Fuel. International Journal of Bio-Technology and Research (IJBTR), 5(4), 27-36.

14. Atrian, A., Majzoobi, G. H., Enayati, M. H., & Bakhtiari, H. (2014). Mechanical and microstructural characterization of Al7075/SiC nanocomposites fabricated by dynamic compaction. International Journal of Minerals, Metallurgy, and Materials, 21(3), 295-303.

15. Chauhan, M. H., Irfan, M., & Chauhan, M. A. (2017). Variation of mechanical properties (tensile strength &microstructure) of al6061/(al2o3 and fly-ash), hybrid metal matrix composite produced by stir casting. International Research Journal of Engineering and Technology, 4(7), 2407-2414.

16. Kittali, P., Satheesh, J., Kumar, G. A., & Madhusudhan, T. (2016). A review on effects of reinforcements on mechanical and tribological behavior of aluminum based metal matrix composites. Int. Res. J. Eng. Technol, 3, 2412.

17. Kumar, G. V., Rao, C. S. P., Selvaraj, N., & Bhagyashekar, M. S. (2010). Studies on Al6061-SiC and Al7075-Al2O3 metal matrix composites. Journal of Minerals and Materials Characterization and Engineering, 9(01), 43.

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